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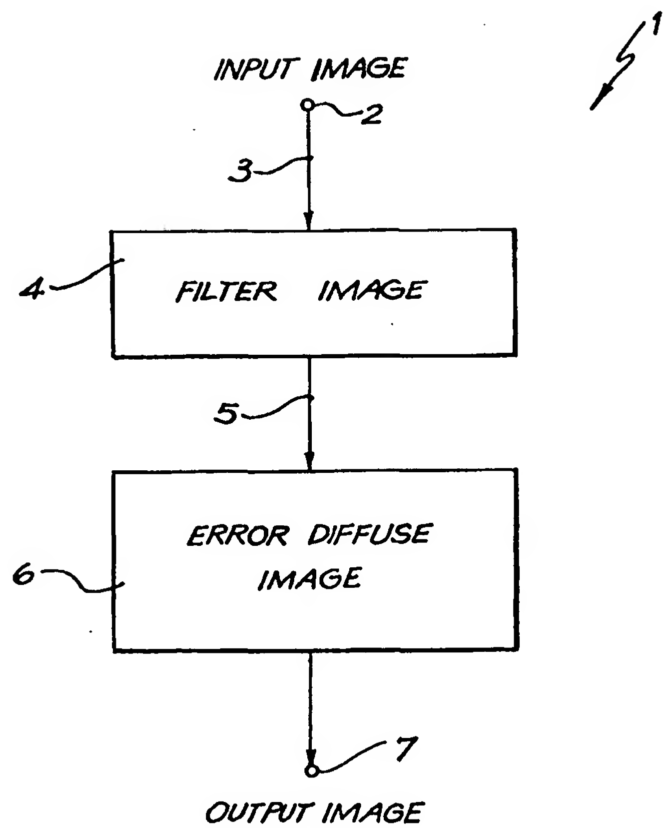
(54) Title: HALFTONING METHOD AND APPARATUS

(57) Abstract

The present invention relates to halftoning images for subsequent transmission. In particular, the invention is a halftoning method and system suitable for halftoning images which are to undergo run length encoding, such as in facsimile transmission. The invention processes the digital words to increase the number of pixels that are fully black and fully white. Then the invention error diffuses the pixels using error coefficients which govern the proportion of the error for each pixel that is distributed to other pixels on the same and following lines. The error coefficient for at least one of the pixels of the current line is reduced, and the error coefficient for at least one of the pixels of the next following line is increased, such that should the error diffused pixels be compressed by run length encoding (where a run of identical symbols is replaced by a symbol and a count) the efficiency of the compression is improved.



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"HALFTONING METHOD AND APPARATUS"

Field of the Invention

The present invention relates to halftoning images for subsequent transmission. In particular, the invention is a halftoning method and system suitable for halftoning images which are to undergo run length encoding, such as in facsimile transmission.

Background of the Invention

Halftoning of continuous tone images into corresponding black and white bit maps is a well travelled and heavily utilised field. Many different techniques have been implemented for the transfer of a continuous tone image to a halftone. In particular, reference is made to the standard text "Digital Halftoning", by Robert Ulichney published 1996 by the MIT press Cambridge, Massachusetts which surveys the field.

One popular form of halftoning is the error diffusion technique thought to have been originally developed by Floyd and Steinberg. In the error diffusion algorithm, each pixel is thresholded to be either totally on (white) or totally off (black) and the error associated with displaying a pixel is distributed to surrounding pixels. Different distributions have been proposed including those of Floyd and Steinberg, Jarvis et. al., Stuckey and Stevenson et. Al. These distributions are defined by a pattern of error coefficients that determine the proportion of the error that is allocated to each of the other pixels. For instance, the Stuckey distribution uses the following coefficients distributed around a current pixel position denoted X:

		X	8/42	4/42
2/42	4/42	8/42	4/42	2/42
1/42	2/42	4/42	2/42	1/42

It has been noticed that images halftoned by error diffusion and subsequently used in compressed transmission systems, such as facsimile, often produce results that are extremely poor in terms both of transmission quality and time.

Summary of the Invention

The invention is a method of halftoning an image comprising rows of pixels represented by digital words, including the steps of:

processing the digital words to increase the number of pixels that are fully black and fully white; then

error diffusing the pixels using error coefficients which govern the proportion of the error for each pixel that is distributed to other pixels on the same and following lines;

where, the error coefficient for at least one of the pixels of the current line is reduced, and the error coefficient for at least one of the pixels of the next following line is increased, such that should the error diffused pixels be compressed by run length encoding (where a run of identical symbols is replaced by a symbol and a count) the efficiency of the compression is improved.

The error coefficients which govern the distribution of error to the current line may generally be less than the error coefficients which distribute error to the following line. In particular, less error may be distributed to the other pixels on the same line than is distributed to any pixel on the following line. And less error may be distributed to the adjacent pixel on the same line than is distributed to the adjacent pixels, including those diagonally adjacent, on the following line.

The errors may be distributed around a current pixel position denoted X as follows:

		X	2/39	2/39
3/39	5/39	8/39	5/39	3/39
1/39	2/39	5/39	2/39	1/39

The filtering may include a step which adds brightness to the image by increasing the value of the digital words. For instance, the values of the digital words may be increased by a predetermined amount such as 34. The increase in value may be related to the dynamic range of brightness of the pixels, such as by a factor approximately 0.125 of the dynamic range.

The filtering may include a step which spreads the midtones and creates black pixels and more white pixels. This may involve mapping the

darkest 0.3% of the total number of pixels within the image to black, and mapping 13% of the total pixels within the image to white. The intermediate values may also be mapped to spread them between black and white extremes. The overall effect is to expand the midtones over the whole intensity range.

The filtering may include a step in which the pixels are weighted by a transfer function that adds white to the image. The transfer function may be represented by a curved line relationship between the digital words of the input and output, and the shape of the curve may be quadratic.

In another aspect, the invention is a halftoning system, including;

An input port to receive digital words which represent the pixels of a continuous tone image:

digital word processing apparatus to increase the number of pixels that are fully black and fully white;

error diffusing apparatus to distribute the error associated with displaying a pixel to surrounding pixels he pixels using error coefficients which govern the proportion of the error for each pixel that is distributed to other pixels on the same and following lines; and

an output port to deliver a digital words which represent the pixels of a half tone image;

where in use, the error coefficient for at least one of the pixels of the current line is reduced, and the error coefficient for at least one of the pixels of the next following line is increased, such that should the half tone image be compressed by run length encoding, the efficiency of the compression is improved.

Brief Description of the Drawings

An example of the halftoning system and method using the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of the halftoning system.

Figure 2 is a graph of the intensity distribution of pixels in a continuous tone image.

Figure 3 is a graph of the intensity distribution of the pixels of Figure 2 after the brightening step of the halftoning process.

Figure 4 is a graph of the intensity distribution of the pixels of Figure 3 after the clipping step of the halftoning process. And

Figure 5 is a graph of the curve processing function used in the curve processing step of the halftoning process.

Detailed Description of Examples of the Invention

Referring first to Figure 1, the halftoning system 1 includes an input port 2 to receive continuous tone images. The continuous tone images 3 are received in the form of a series of pixels each represented as an 8-bit digital word so that they are able to have a grey value ranging from 0 (black) up to 255 (white). The words are arranged to represent the image starting at the left of the top row of pixels, then running along that row to the right. The top row is followed by the second row from left to right, and so on.

The input port 2 is connected to a filtering unit 4, and the received images are fed one word at a time to the filtering unit 4. In Filtering unit 4 the image undergoes three filtering processes, namely brightening, clipping and colour curve processing. The filtering processes operate to produce a filtered image 5 in which the grey pixels have been moved towards black or white.

The filtering unit 4 is connected to a error diffusing unit 6, and the filtered images 5 are fed to fed to the error diffusing unit 4. In error diffusing unit 6 the error coefficients which govern the distribution of error to the current line are generally less than the error coefficients which distribute error to the following line.

The output of the error diffusing unit 6 is connected to an output port 7 which may be connected to transmission apparatus.

The filtering and error diffusing processes will now be described in greater detail with reference to Figures 2 to 6.

In Figure 2 a continuous tone image is typically seen to have a fairly even spread 21 of mid-grey pixels but fewer pixels having close to black and white.

The operation of brightening an image involves adding a fixed intensity component to the image, in this example the value "34" is added to the digital number representing each pixel in the image. Pixels having a starting value of 221 or higher cannot, of course, increase their value above 255 and are clamped at extreme white. Figure 3 shows the resulting

distribution 22 of intensities after the brightening process. Importantly, at the extreme white end, a substantial number of pixels 23 are now fully white. There are also no black pixels or pixels having a grey value less than 34.

A clip operation then spreads the midtones and creates black pixels and more white pixels. The clipping involves mapping the darkest 0.3% of the total number of pixels within the image to black. And mapping 13% of the total pixels within the image to white. The intermediate values are also mapped to spread them between black and white extremes as shown by the distribution 24 in Figure 4. The overall effect is to expand the midtones over the whole intensity range.

In the colour curve processing step, a quadratic function, as shown by the curve 25 in Figure 5 is used to add white to the image. This also has the effect of lowering the number of mid-grey pixels.

The overall result of the filtering is to increase the number of pixels that are fully black and fully white.

The next step is to error diffuse 13 the resultant image using the error diffusion algorithm based on the Stuckey form of coefficients, where the errors are distributed around a current pixel position denoted X as follows:

		X	2/39	2/39
3/39	5/39	8/39	5/39	3/39
1/39	2/39	5/39	2/39	1/39

In this algorithm the error associated with each pixel is distributed or apportioned to the surrounding pixels in the fractions as indicated. Overall the error diffusion algorithm ensures that a substantial amount of the error is distributed to a next line of the image rather than adjacent pixels on a current line. The error coefficients which govern the distribution of error to the current line are generally less than the error coefficients which distribute error to the following line. In particular, less error is distributed to the other pixels on the same line than is distributed to any pixel on the following line. And less error is distributed to the adjacent pixel on the same line than is distributed to the adjacent pixels, including those diagonally adjacent, on the following line.

Although the invention has been described with reference to a particular example it should be appreciated that it may be implemented in many other ways. For example, the value added to the digital words to increase brightness need not be "34", and other numbers may also be used. The clipping percentages may also be varied from the darkest 0.3% and the lightest 13%. Further, other curves and non-linear transfer functions may be used in the curve processing step.

The filtering steps can be implemented in the order stated or alternatively in a permuted order.

The error diffusion step exemplified used a Stuckey form of coefficients, but other systems of coefficients may also be used.

It should be understood that the invention may be implemented in both hardware and software. In particular, the error diffusion algorithm could be implemented by merely changing of coefficients in an existing software implementation. Similarly, a hardware implementation could simply be reengineered to change the coefficients so as to distribute the error in accordance with the principles of the present invention.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:

1. A method of halftoning an image comprising rows of pixels represented by digital words, including the steps of:

processing the digital words to increase the number of pixels that are fully black and fully white; then

error diffusing the pixels using error coefficients which govern the proportion of the error for each pixel that is distributed to other pixels on the same and following lines;

where, the error coefficient for at least one of the pixels of the current line is reduced, and the error coefficient for at least one of the pixels of the next following line is increased, such that should the error diffused pixels be compressed by run length encoding the efficiency of the compression is improved.

2. A method according to claim 1, where the error coefficients which govern the distribution of error to the current line are less than the error coefficients which distribute error to the following line.

3. A method according to claim 2, where less error is distributed to the other pixels on the same line than is distributed to any pixel on the following line.

4. A method according to claim 2, where less error is distributed to the adjacent pixel on the same line than is distributed to the adjacent pixels.

5. A method according to claim 4, where less error is distributed to the adjacent pixel on the same line than is distributed to the adjacent pixels, including those diagonally adjacent, on the following line.

6. A method according to claim 1, where the errors are distributed around a current pixel position denoted X as follows:

		X	2/39	2/39
3/39	5/39	8/39	5/39	3/39
1/39	2/39	5/39	2/39	1/39

7. A method according to claim 1, where the filtering includes a step which adds brightness to the image by increasing the value of the digital words.

8. A method according to claim 1, where the filtering includes a step which spreads the midtones and creates black pixels and more white pixels.

9. A method according to claim 1, where the filtering includes a step in which the pixels are weighted by a transfer function that adds white to the image.

10. A halftoning system, including:

an input port to receive digital words which represent the pixels of a continuous tone image;

digital word processing apparatus to increase the number of pixels that are fully black and fully white;

error diffusing apparatus to distribute the error associated with displaying a pixel to surrounding pixels he pixels using error coefficients which govern the proportion of the error for each pixel that is distributed to other pixels on the same and following lines; and

an output port to deliver a digital words which represent the pixels of a half tone image;

where in use, the error coefficient for at least one of the pixels of the current line is reduced, and the error coefficient for at least one of the pixels of the next following line is increased, such that should the half tone image be compressed by run length encoding, the efficiency of the compression is improved.

11. A system according to claim 10, where the error coefficients which govern the distribution of error to the current line are less than the error coefficients which distribute error to the following line.

12. A system according to claim 11, where less error is distributed to the other pixels on the same line than is distributed to any pixel on the following line.

13. A system according to claim 11, where less error is distributed to the adjacent pixel on the same line than is distributed to the adjacent pixels.

14. A system according to claim 13, where less error is distributed to the adjacent pixel on the same line than is distributed to the adjacent pixels, including those diagonally adjacent, on the following line.

15. A system according to claim 10, where the errors are distributed around a current pixel position denoted X as follows:

		X	2/39	2/39
3/39	5/39	8/39	5/39	3/39
1/39	2/39	5/39	2/39	1/39

16. A system according to claim 10, where the filtering includes a step which adds brightness to the image by increasing the value of the digital words.

17. A system according to claim 10, where the filtering includes a step which spreads the midtones and creates black pixels and more white pixels.

18. A system according to claim 10, where the filtering includes a step in which the pixels are weighted by a transfer function that adds white to the image.

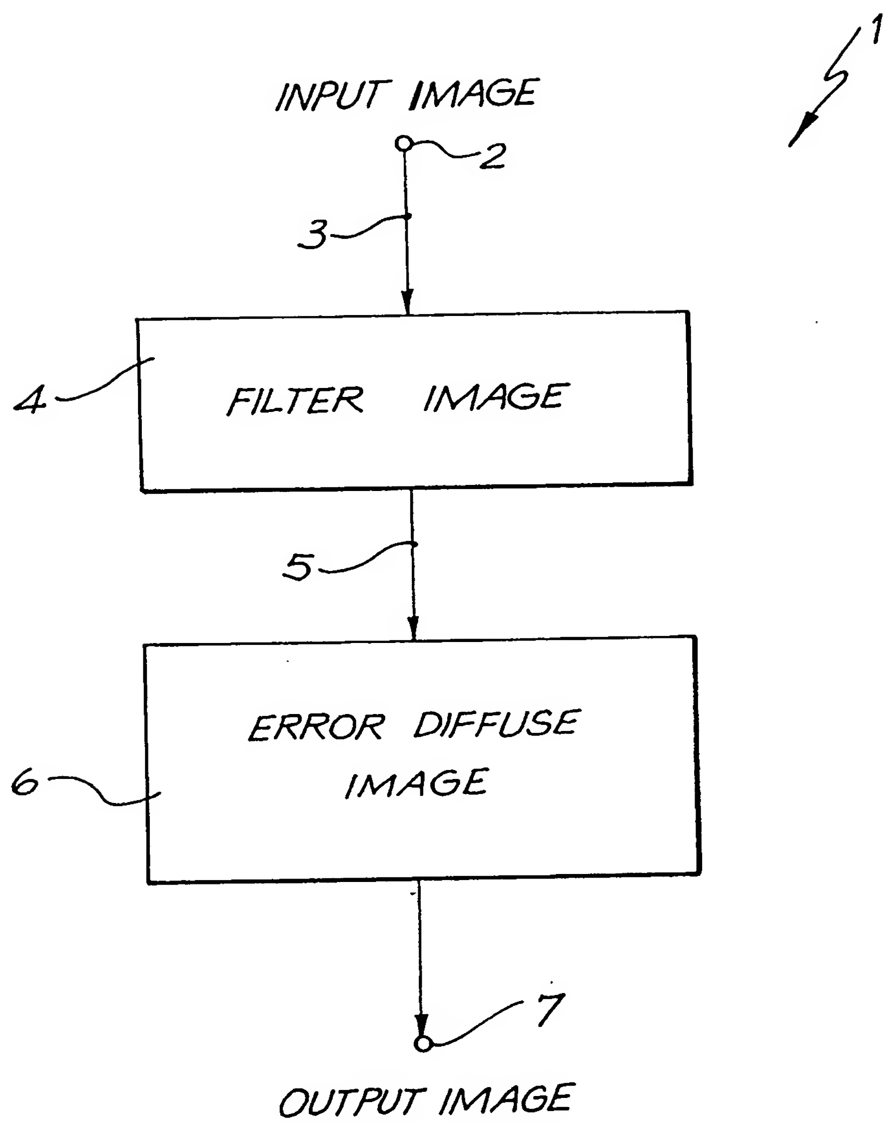
1
INPUT IMAGE
2
3
4
FILTER IMAGE
5
6
ERROR DIFFUSE IMAGE
7
OUTPUT IMAGE

FIG. 1

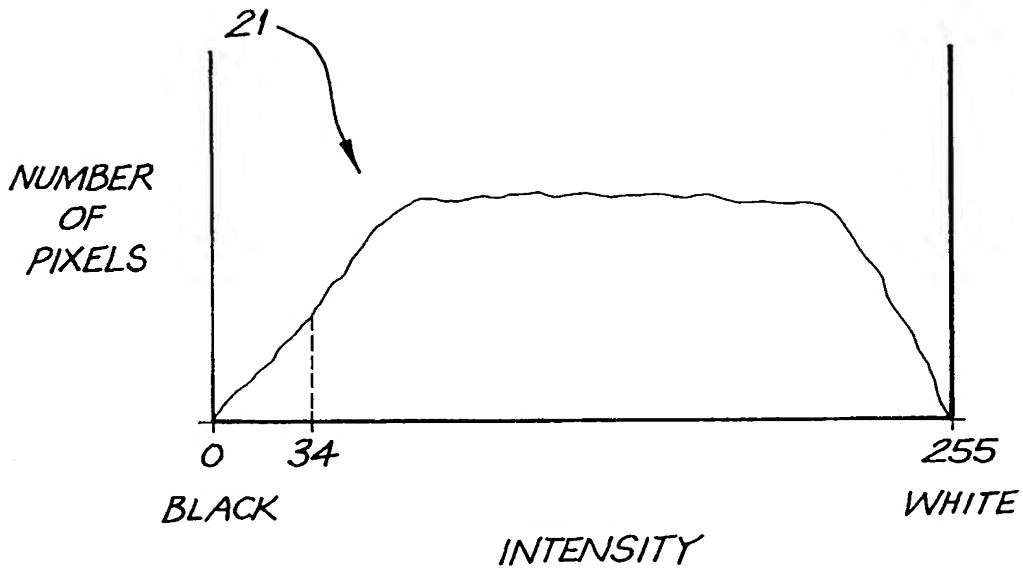
21
NUMBER OF PIXELS
0
34
255
BLACK
WHITE
INTENSITY

FIG. 2

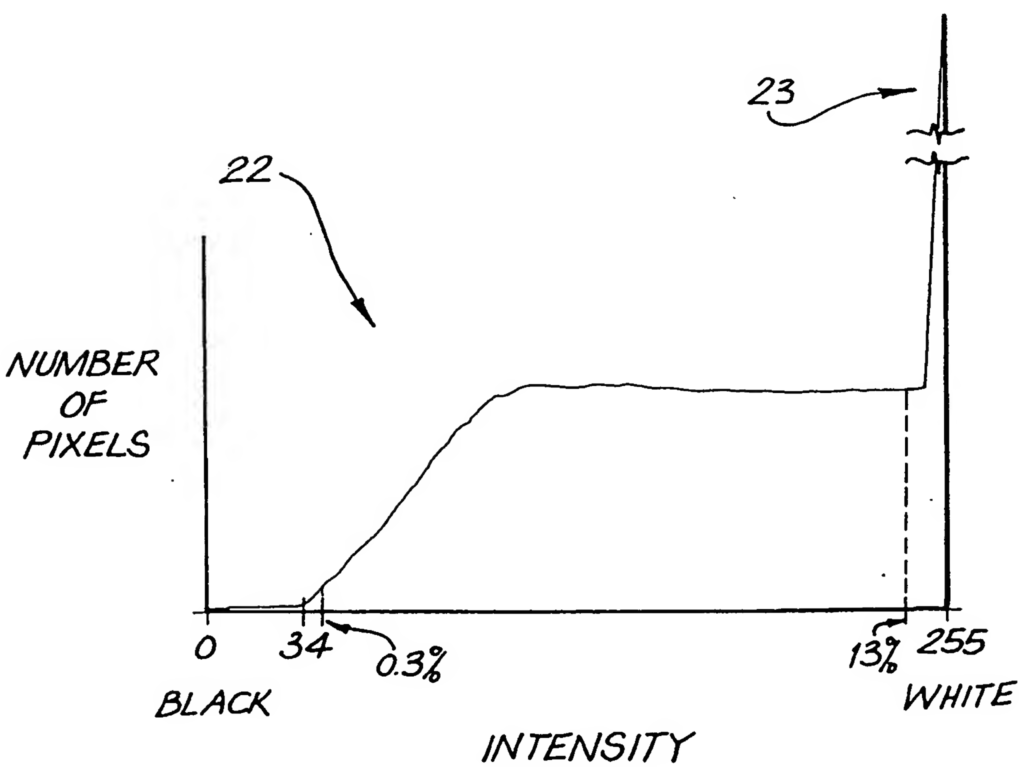
23
22
NUMBER OF PIXELS
0
34
0.3%
13%
255
BLACK
WHITE
INTENSITY

FIG. 3

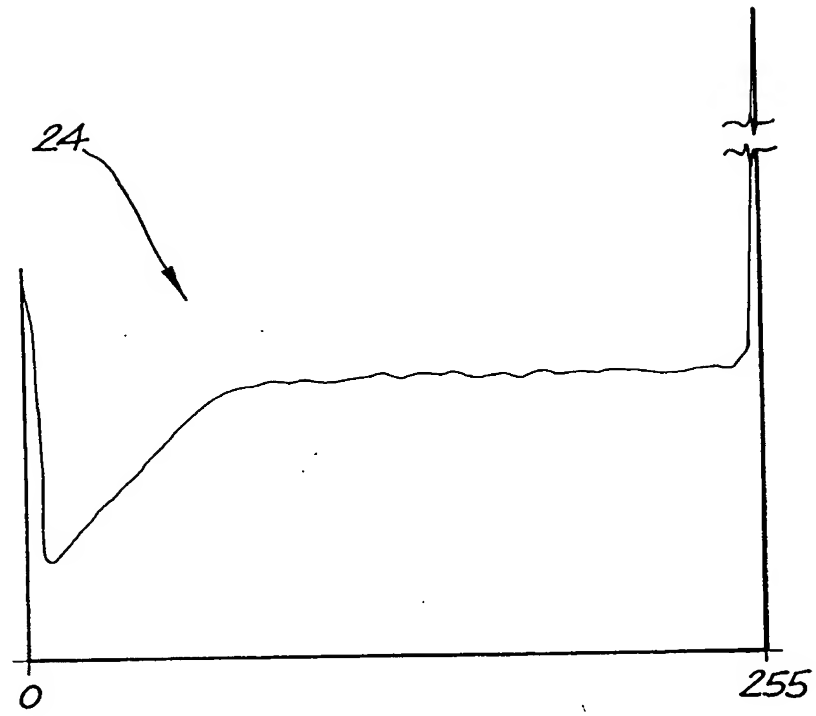

FIG. 4

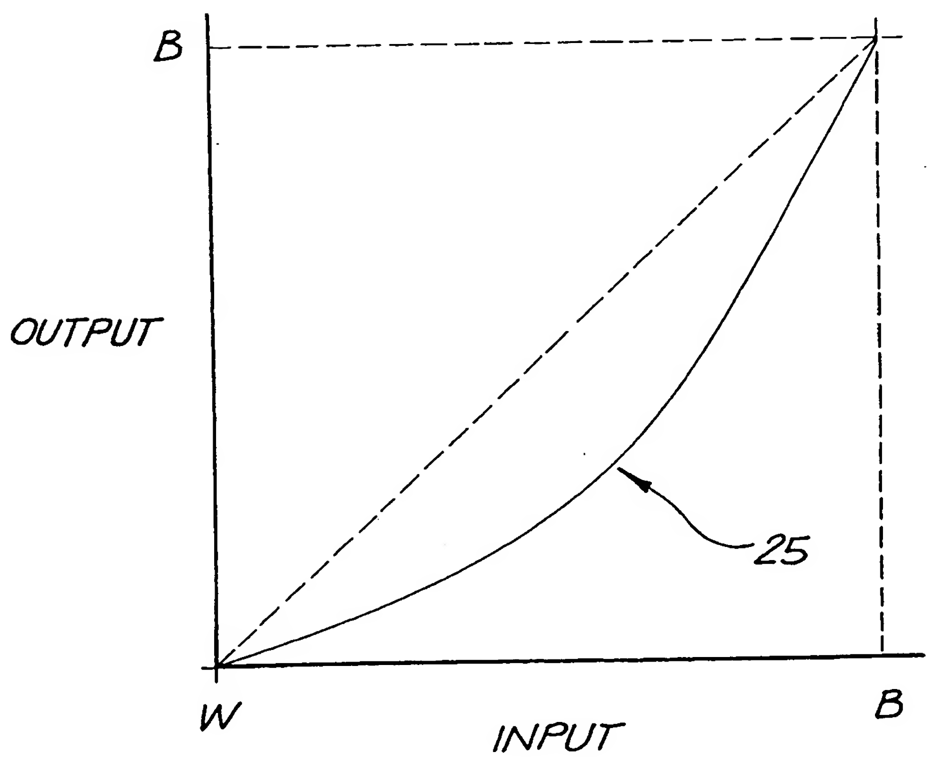

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 98/00884

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl^6: H04N 1/405

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : H04N 1/--; H03M --/--

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT : (Halfton:)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5535019 A (ESCHBACH) 9 July 1996	1, 10
X	EP 696129 A2 (XEROX CORPORATION) 7 February 1996	1, 10
X	EP 500267 A2 (AT & T) 26 August 1992	1, 10
A	US 5657137 A (PEROMAL, Jr. et al) 12 August 1997	1-18
A	US 5045952 A (ESCHBACH) 3 September 1991	1-18

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU 98/00884

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5535019	EP	702482	JP	8107500		
EP	696129	BR	9503501	JP	8065515		
EP	500267	JP	5091331	US	5475497	US	5309526
		US	5682442	US	5469268	CA	2014935
		EP	396368	HK	337/96	JP	2305191
		US	5517581				
US	5657137	EP	569206	EP	739126	JP	6038033
		US	5377024	US	5537228	US	5473446
		US	5510910	EP	665678	JP	7222020
		EP	665674	JP	7222019		
US	5045952	EP	414505	JP	3165664		

END OF ANNEX